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Fletcher et al.

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(54) **CHECK VALVE INSERT DEFINING AN OPEN POSITION AND CHECK VALVES HAVING SAME**

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CPC ***F16K 15/023*** (2013.01); ***F16K 25/00*** (2013.01); ***F16K 27/0209*** (2013.01); *F02M 35/10229* (2013.01)

(58) **Field of Classification Search**
CPC . F16K 15/023; F16K 15/141; Y10T 137/7879
See application file for complete search history.

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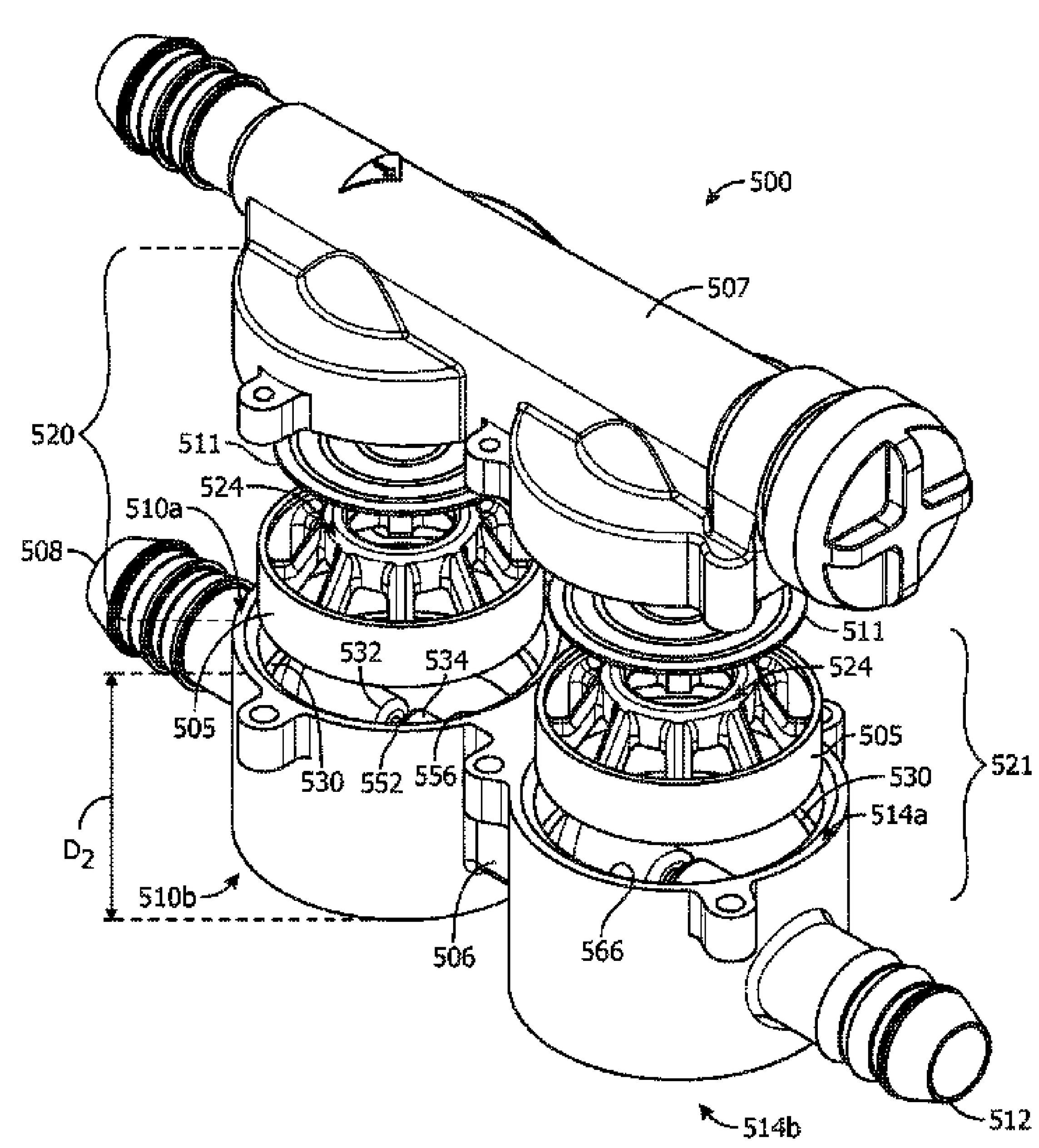
(57) **ABSTRACT**

Check valve inserts define a valve seat for an open position of a check valve and have an outer support seatable in an internal chamber of the check valve and have an inner annular ring spaced radially inward from the outer support by a rib that angles axially toward a central longitudinal axis to position an upper surface of the inner annular ring a distance axially beyond an upper surface of the outer support. Check valves have a housing defining an inlet port, an outlet port, and a chamber in fluid communication with the inlet and outlet ports, have the check valve insert seated with the chamber, and have a seal disc moveable within the chamber between the open position defined by the inner annular ring of the check valve insert and a closed position. The seal disc is translatable in response to a pressure difference across the seal disc.

17 Claims, 9 Drawing Sheets



(51) **Int. Cl.**
F16K 25/00 (2006.01)
F02M 35/10 (2006.01)

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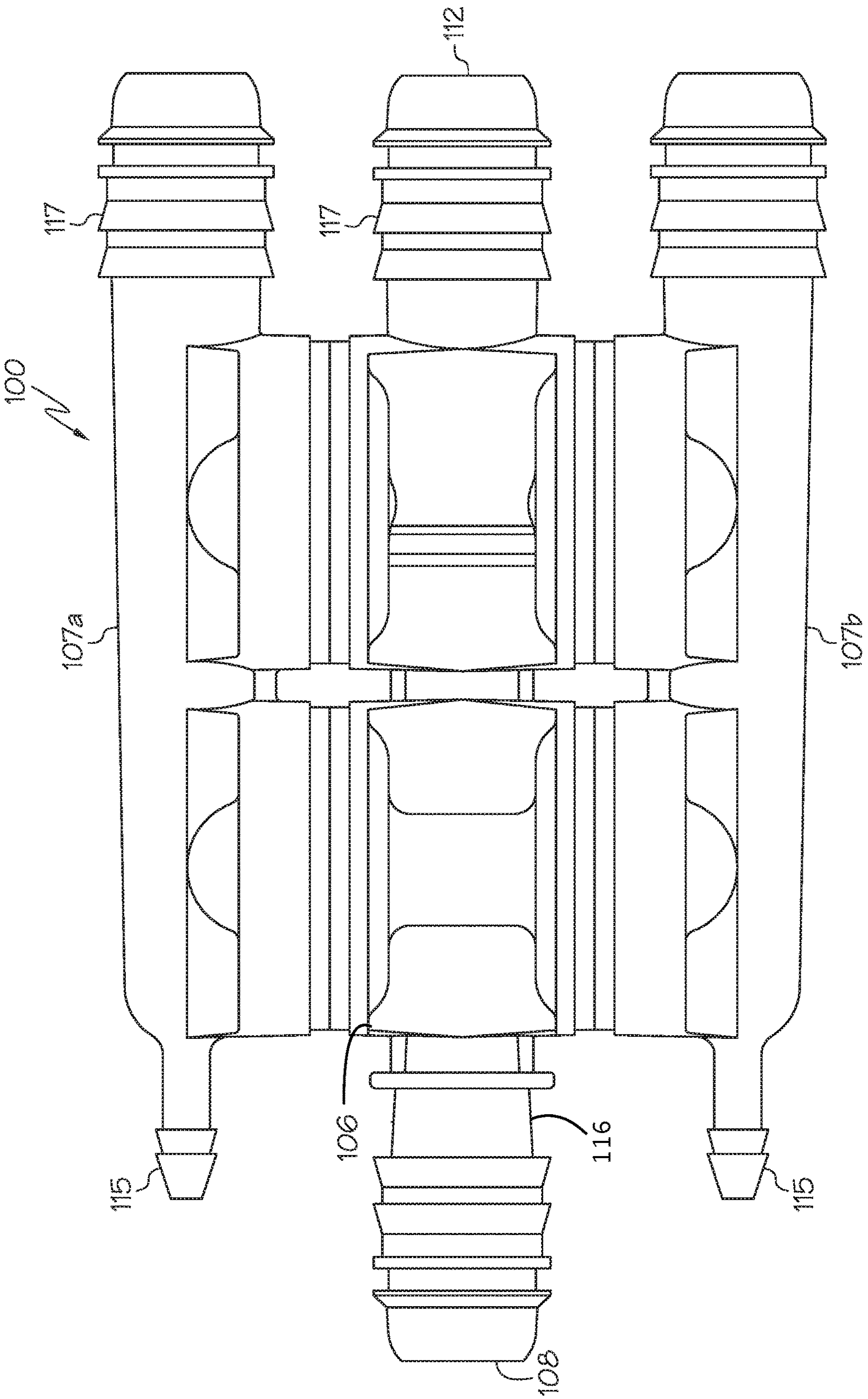


FIG. 1
(Prior Art)

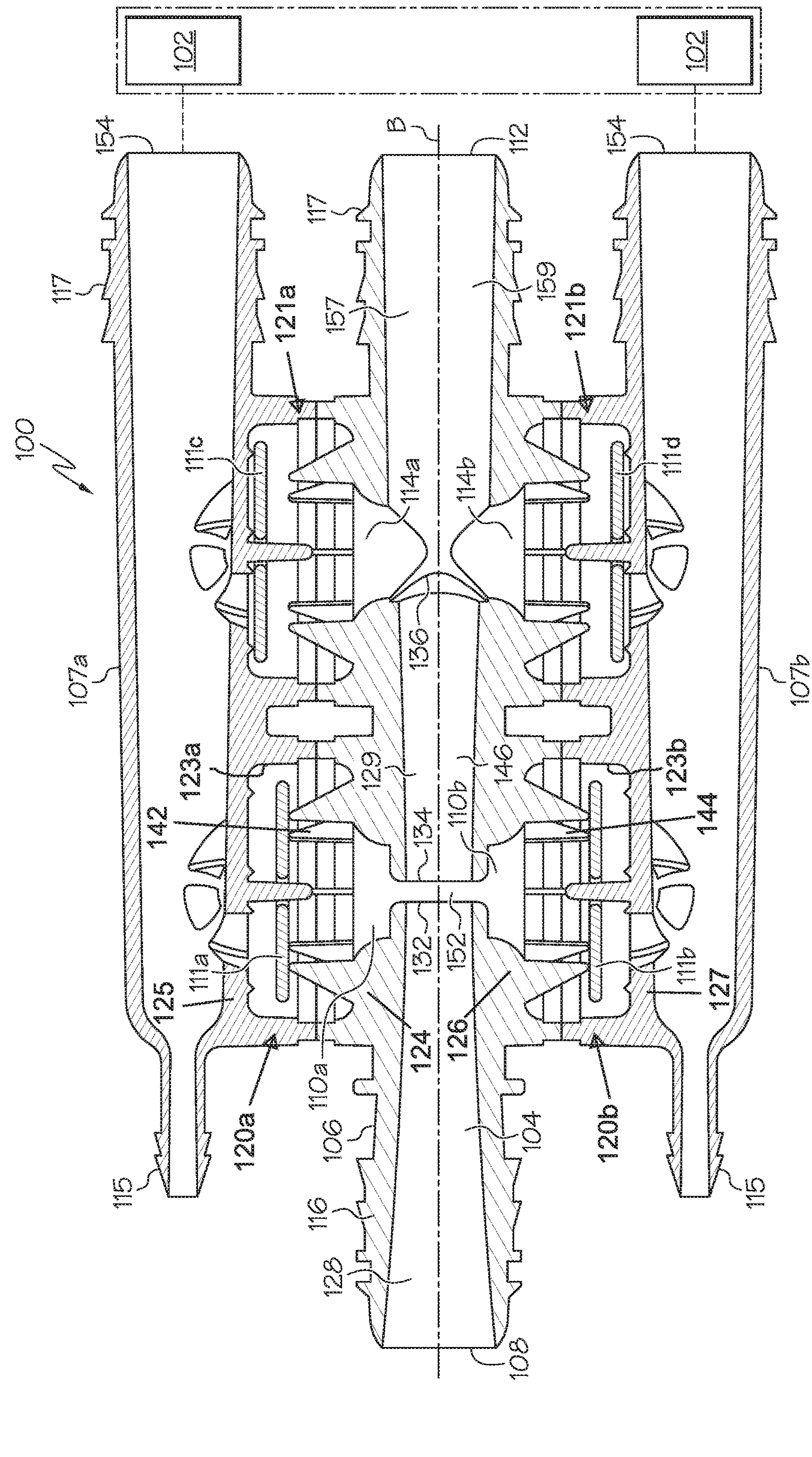


FIG. 2
(Prior Art)

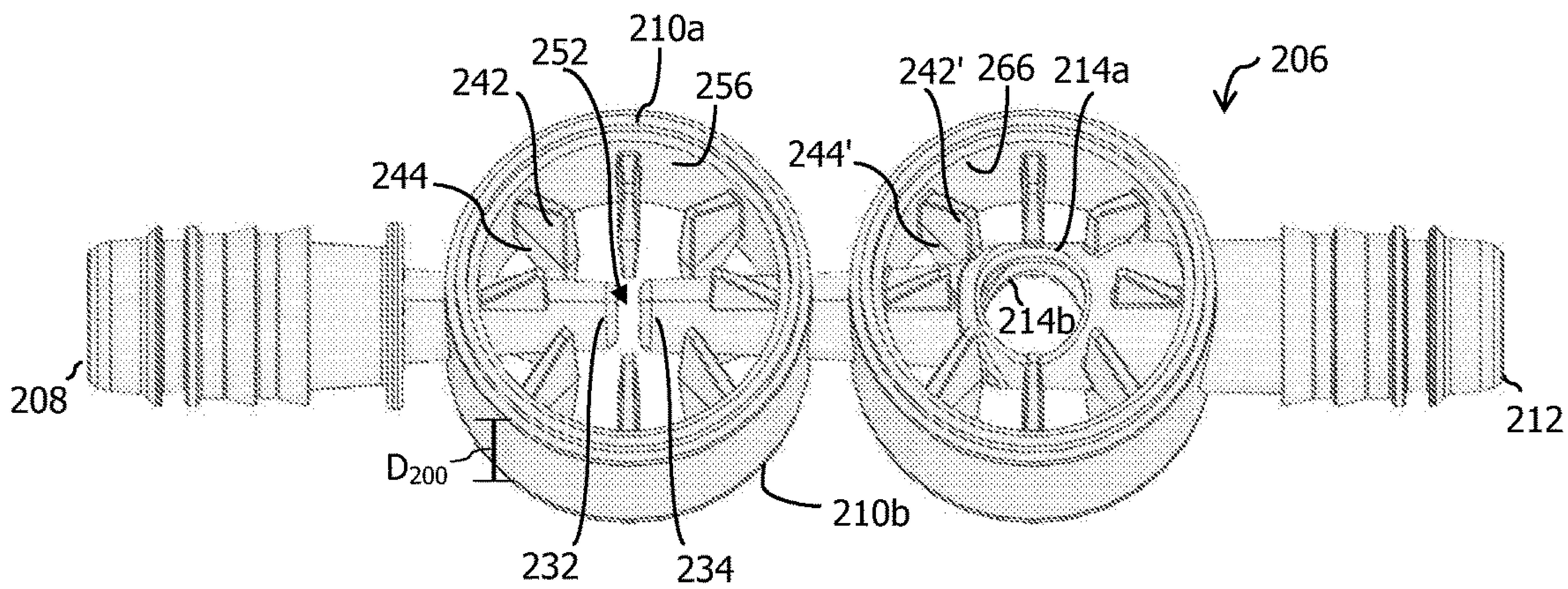


FIG. 3 (Prior Art)

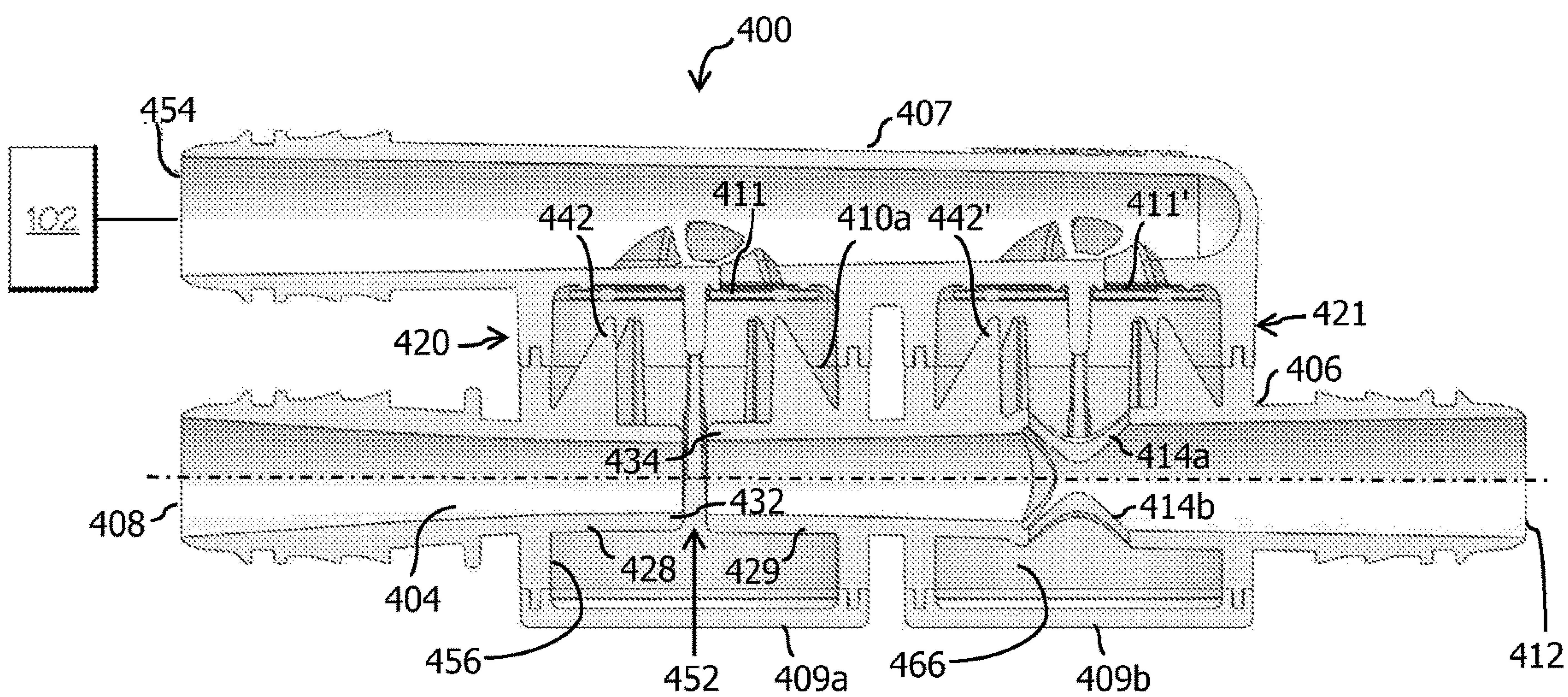


FIG. 4 (Prior Art)

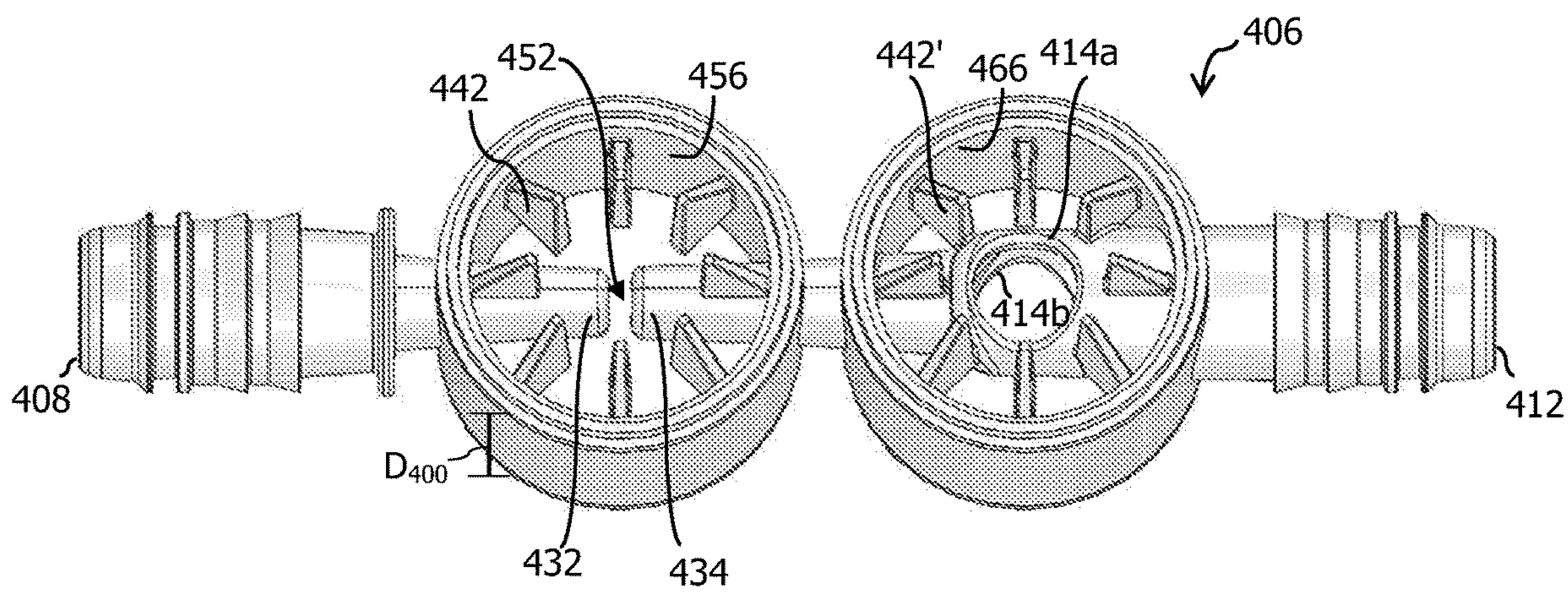
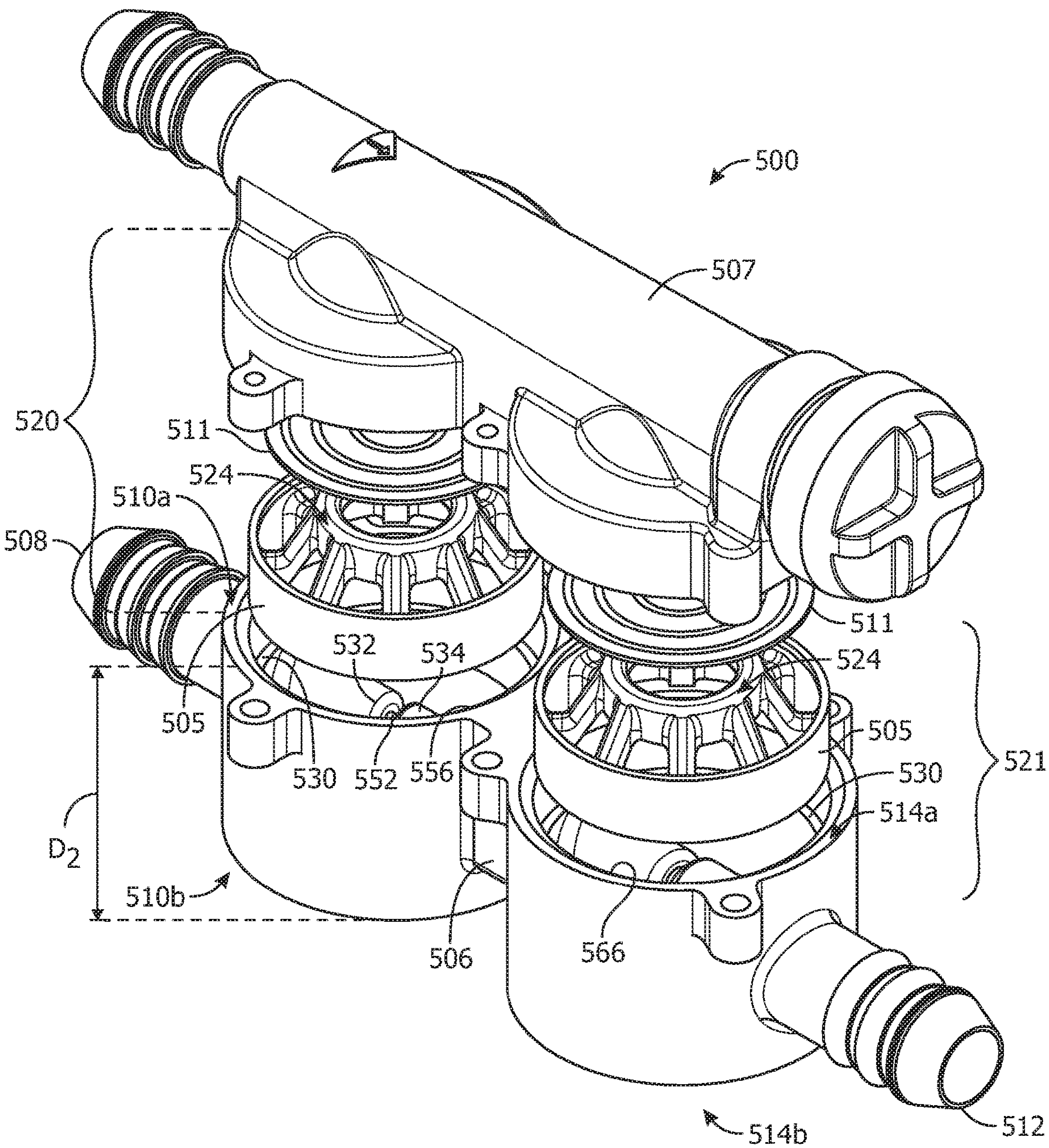


FIG. 5 (Prior Art)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507
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511
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510a
508
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532
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556
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D_2
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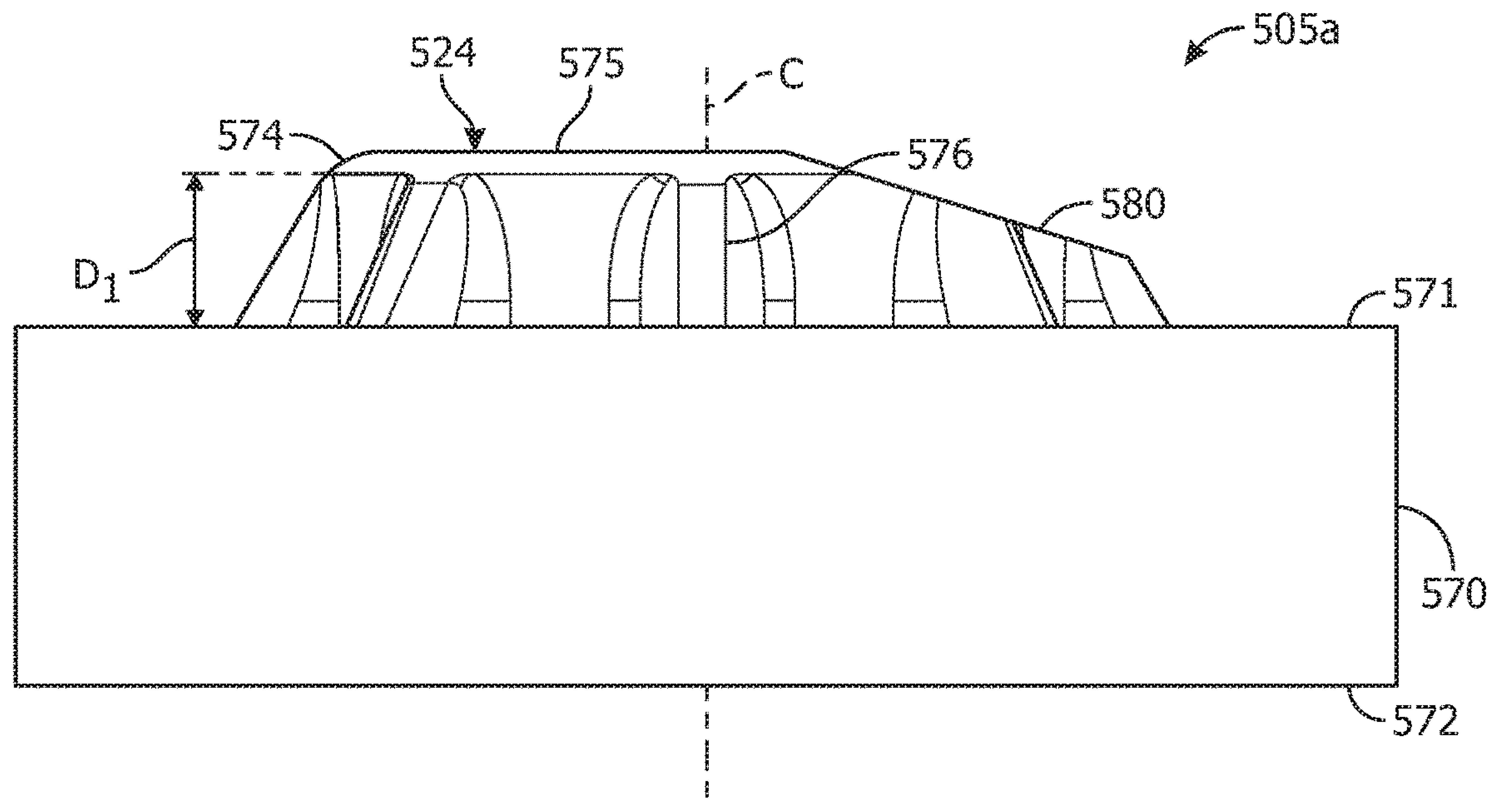
566
512
514b

FIG. 6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D_1
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FIG. 7

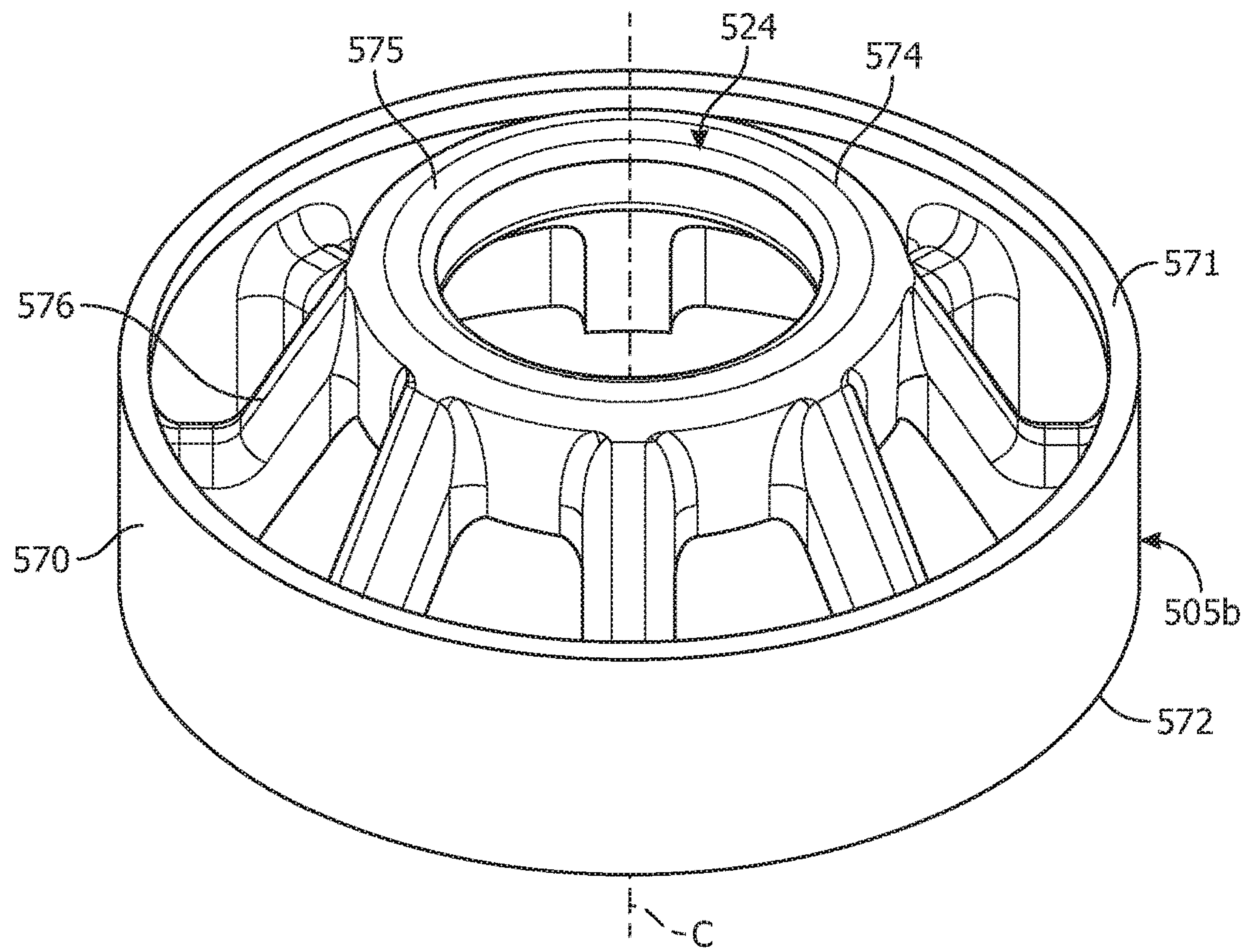
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FIG. 8

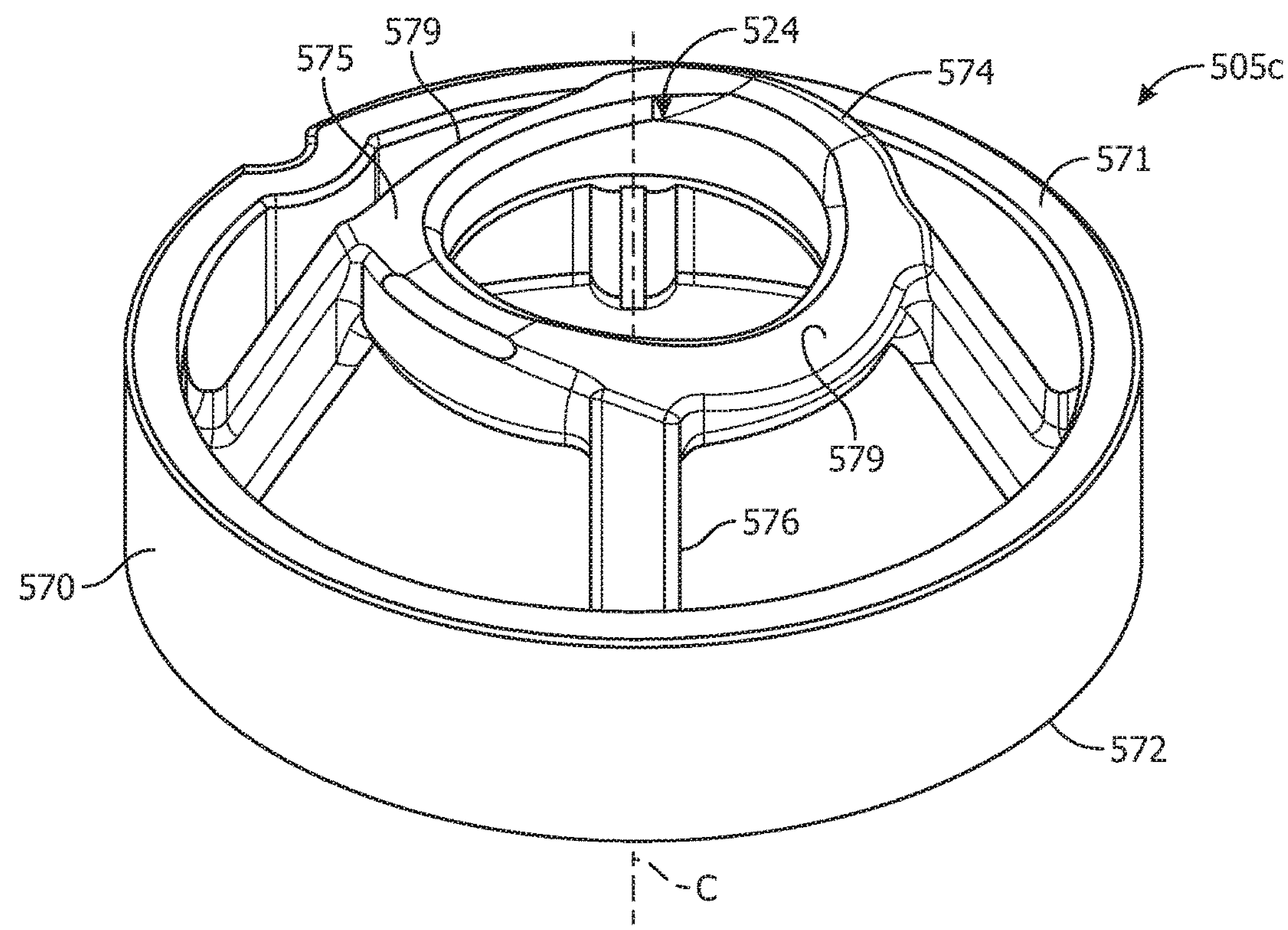
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FIG. 9

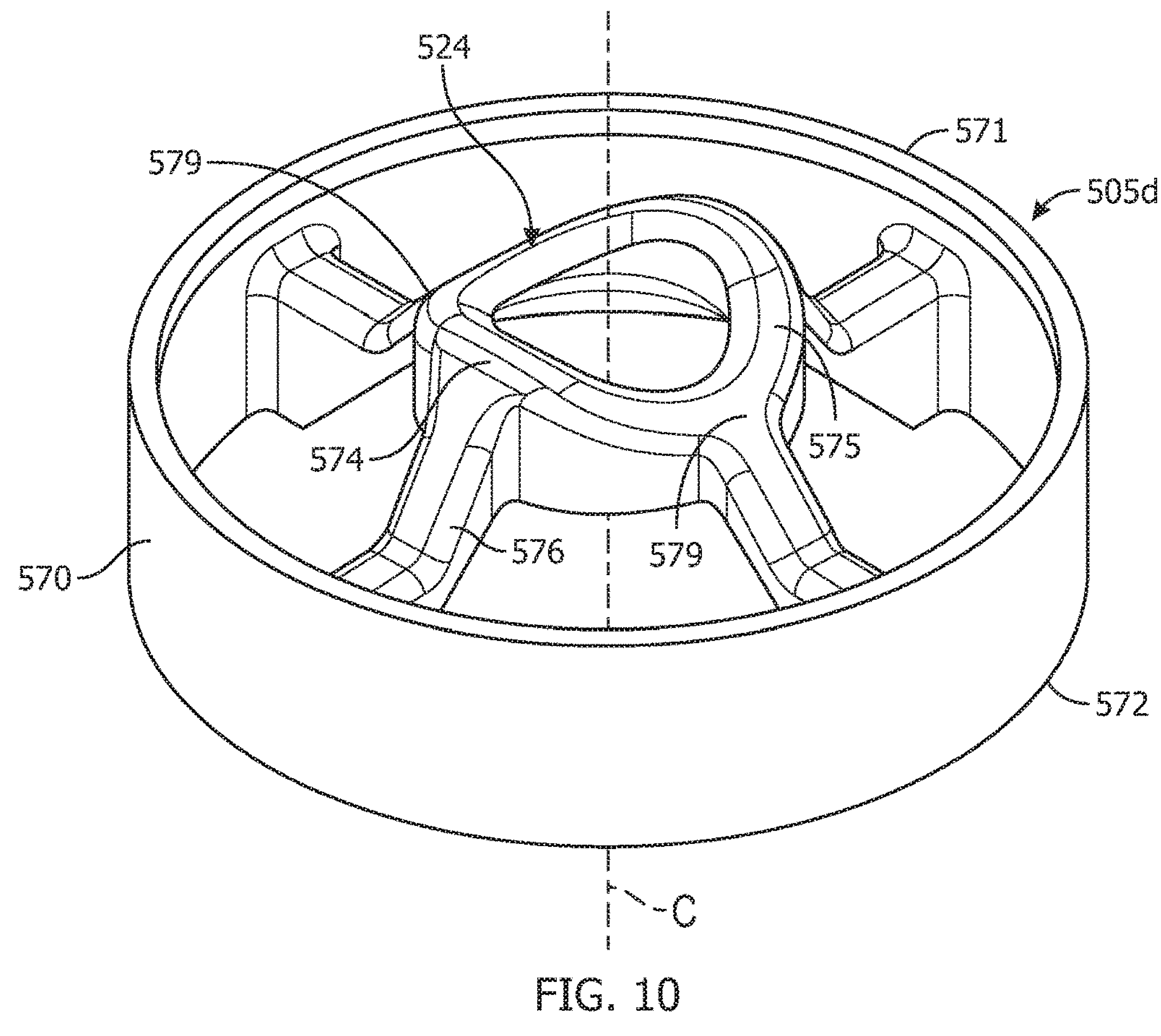
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FIG. 10

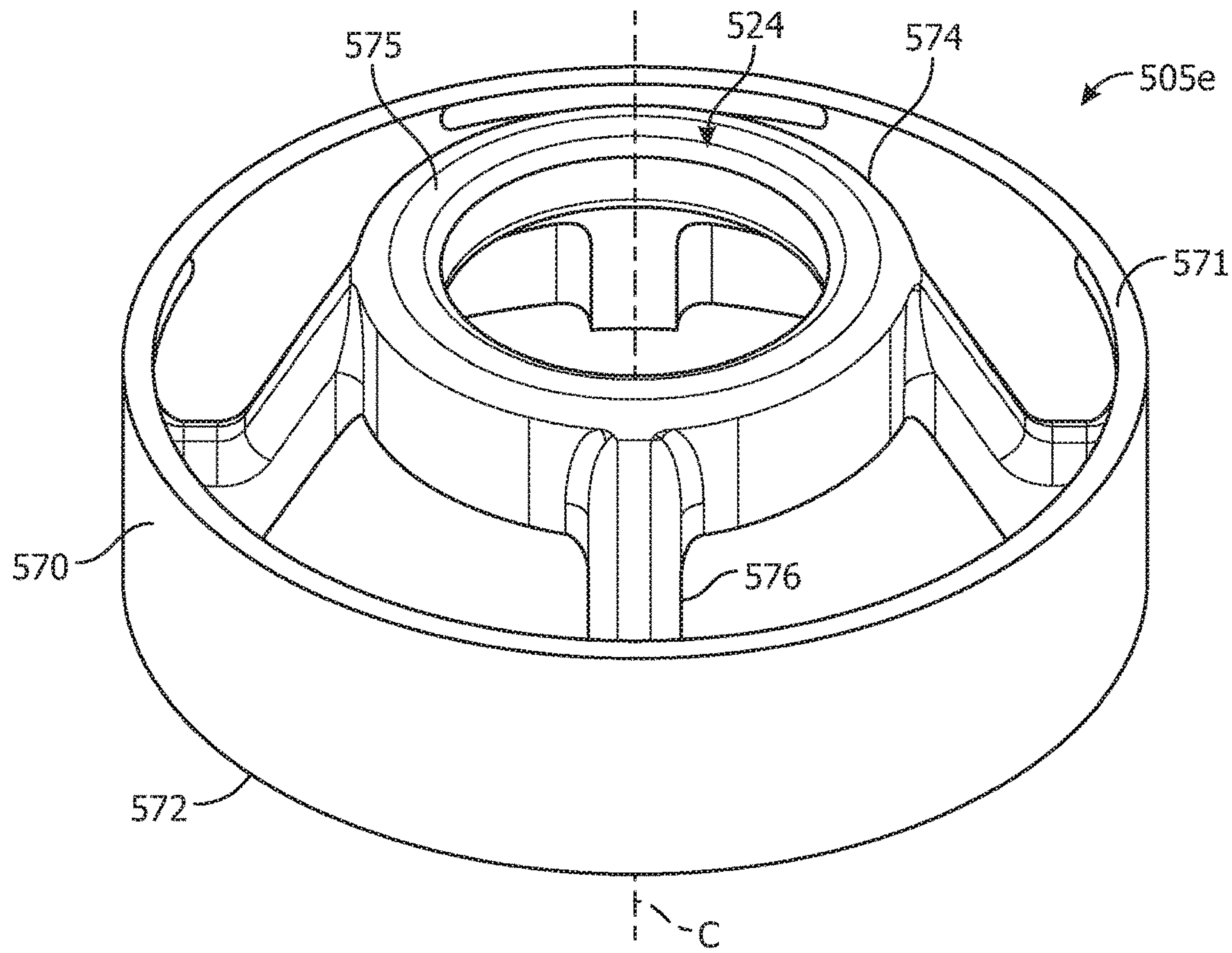
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FIG. 11

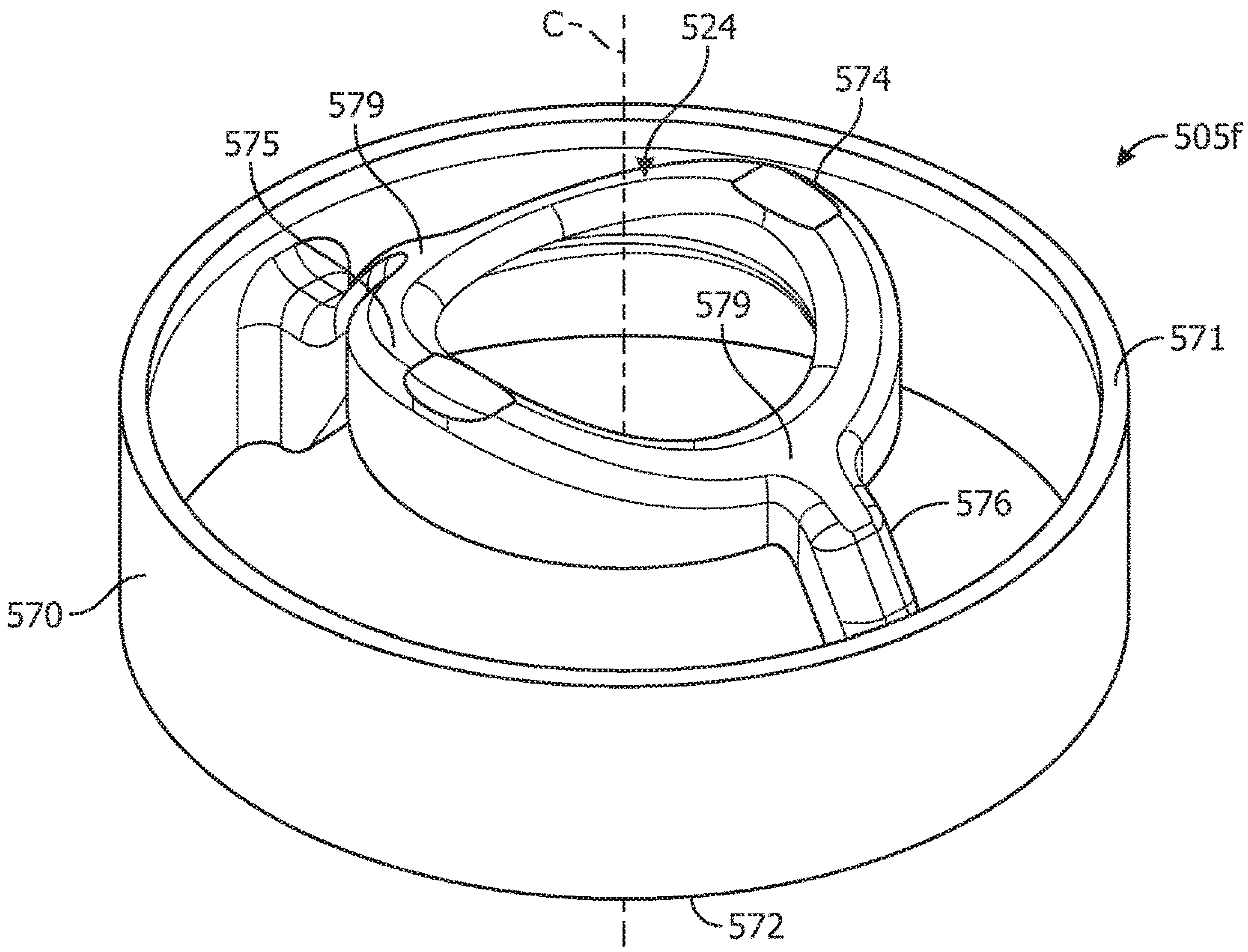
C
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FIG. 12

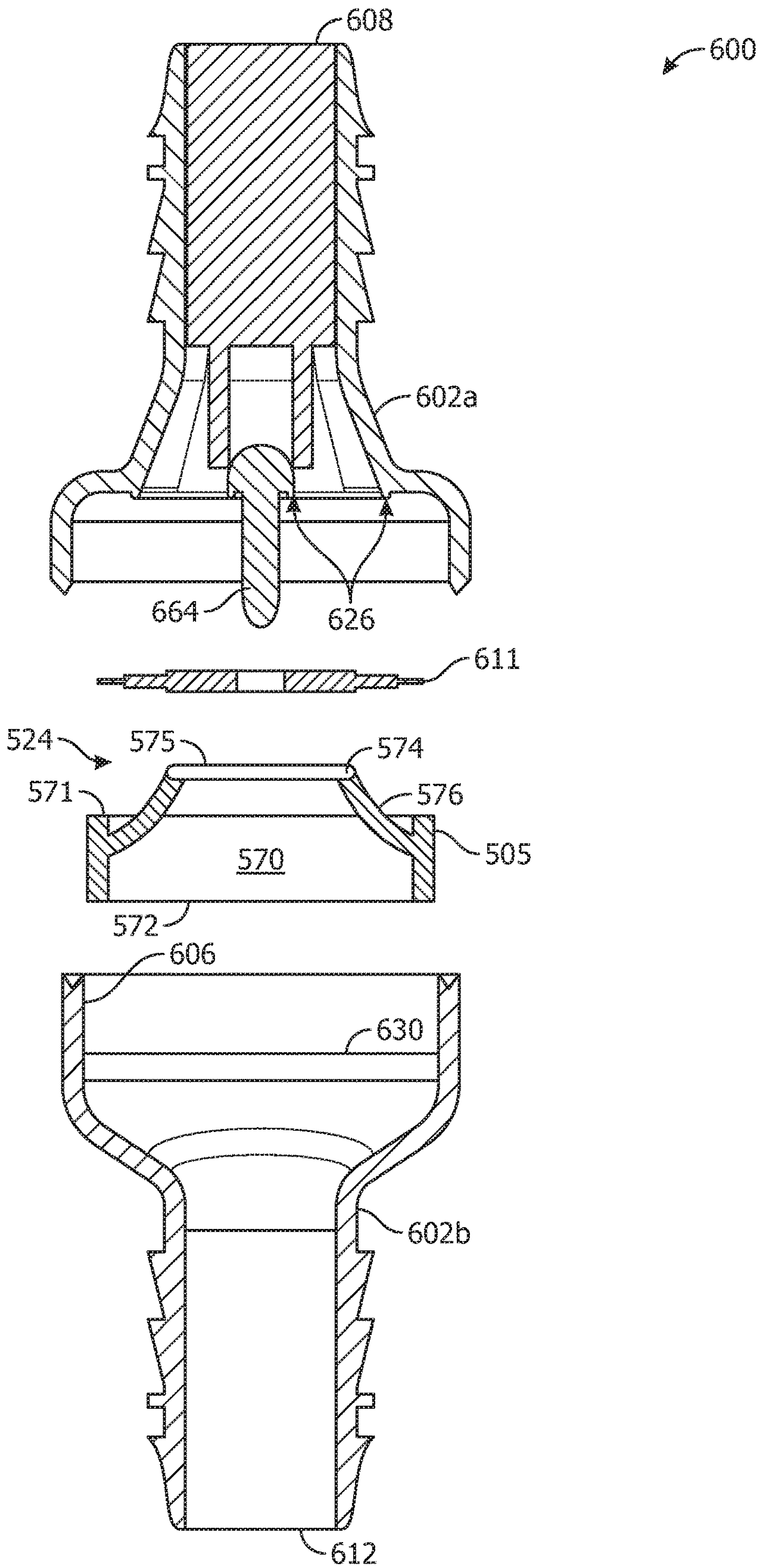
608
600
602a
664
626
611
524
575
574
571
576
505
570
572
606
630
602b
612

FIG. 13

CHECK VALVE INSERT DEFINING AN OPEN POSITION AND CHECK VALVES HAVING SAME

TECHNICAL FIELD

This application relates to check valves having an insert that defines a valve seat for an open position for a translatable seal disc translatable only in response to pressure differentials across the seal disc. The check valves may be standalone units or may be integral with a Venturi device as a check valve for a Venturi gap and/or a bypass port.

BACKGROUND

Engines, for example vehicle engines, have included aspirators or ejectors for producing vacuum, and/or check valves. Typically, the aspirators are used to generate a vacuum that is lower than engine manifold vacuum by inducing some of the engine air to travel through a Venturi gap. The aspirators may include check valves therein or the system may include separate check valves. As shown in co-owned U.S. Pat. No. 9,534,704, issued Jan. 3, 2017, and U.S. Pat. No. 9,581,258, issued Feb. 28, 2017, each check valve, whether built into a Venturi device or as a separate check valve unit, includes a first valve seat defined by a plurality of radially spaced apart fingers to form a support/seat for a translatable seal disc that defines the open position of the check valve and a second valve seat that defines the closed position of the check valve. In these check valve units, the first and second valve seats are integrally molded components of the housing that defines the internal chamber of the check valve unit, and as a molded component are made of the same durable material as the housing.

The above-described check valve units can be improved, as disclosed herein, to reduce the stress on the translatable seal disc, which is a result of the shape, spacing, and material of the plurality of radially spaced apart fingers as well as the pressure applied to the seal disc by the pressure differential in the system. Thus, there is a need to improve the first valve seat to reduce the stress on the seal disc, and a need to improve the ease manufacture and assembly of a check valve unit.

SUMMARY

In all aspects, check valve inserts are disclosed herein that are insertable and seatable in a chamber of a check valve unit. Each check valve insert has an outer support seatable in an internal chamber of a check valve unit and having an upper surface and a lower surface, and an inner annular ring spaced radially inward from the outer support by a rib that angles axially toward a central longitudinal axis to position an upper surface of the inner annular ring a distance axially beyond the upper surface of the outer support. The inner annular ring defines a first seat for an open position of the check valve unit.

In all aspects, the outer support is an annular ring or a polygonal-shaped ring and the inner annular ring is circular or oval in shape. Also, the upper surface of the inner annular ring is a continuous surface in one plane perpendicular to the central longitudinal axis, undulates with two opposing troughs, or is angled downward and radially outward toward the outer support over a minor arc extending 20 degrees up to 170 degrees. Further, a plurality of circumferentially spaced apart ribs space the inner annular ring from the outer support.

In another aspect, any of the check valve inserts described above is seated in a chamber of a check valve unit. The check valve unit has a housing defining an inlet port, an outlet port, and the chamber, which is in fluid communication with the inlet port and the outlet port, thereby defining a flow path from the inlet port through the chamber to the outlet port. The chamber defines a seal seat for a closed position and has a shoulder protruding inward. The check valve insert is seated on the shoulder in the chamber and a seal disc translatable within the chamber is present that translates in response to a pressure difference across the seal disc itself between an open position seated on the upper surface of the inner annular ring of the check valve insert and the closed position.

In one embodiment, the outlet port of the check valve unit is a Venturi gap of a Venturi device or a bypass port of a Venturi device. The bypass port may be positioned downstream of a Venturi gap.

In another aspect, any of the check valve inserts described above is seated in a chamber of a Venturi device. The Venturi device has a body defining a passageway having a motive section and a discharge section spaced a distance apart from one another to define a Venturi gap, both of which converge toward the Venturi gap, and defining a chamber housing the Venturi gap and having a first suction port in fluid communication with the Venturi gap. The chamber has a first shoulder protruding inward and positioned a pre-selected distance between the Venturi gap and the first suction port. The check valve insert is seated on the shoulder in the chamber and a seal disc translatable within the chamber is present that translates in response to a pressure difference across the seal disc itself between an open position seated on the upper surface of the inner annular ring of the check valve insert and the closed position. The Venturi device include a first suction housing sealingly connected to the first suction port to collectively form a first check valve chamber, and the suction housing defines a valve seat for the closed position.

In all aspects, the body of the Venturi device further defines a second suction port in fluid communication with the Venturi gap and either a cap sealingly connected to the second suction port or a second suction housing sealingly connected to the second suction port to collectively form a second check valve chamber. When the second suction housing is present, the chamber of the body has a second shoulder protruding inward and positioned a pre-selected distance between the Venturi gap and the second suction port and a second check valve insert seated on the second shoulder in the chamber. The second check valve insert is any of the check valve inserts described above. Further, a second seal disc translatable in response to a pressure difference across the second seal disc is present within the second check valve chamber and translates between an open position seated on the upper surface of the inner annular ring of the second check valve insert and a closed position.

In all aspects of the Venturi device, an outlet end of the motive section extends into the chamber defined by the body at a position where the chamber provides fluid flow around the entire outer surface of the outlet end, and an inlet end of the discharge section extends into the chamber at a position where the chamber provides fluid flow around the entire outer surface of the inlet end of the discharge section. Also, the body may define a bypass port downstream of the first suction port.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a side view of one embodiment of a Venturi device.

FIG. **2** is a side, longitudinal cross-sectional, plan view of the Venturi device of FIG. **1**.

FIG. **3** is a side, perspective view of an alternate embodiment of just the body of the Venturi device of FIG. **2**.

FIG. **4** is a side, longitudinal cross-sectional, plan view of another embodiment of a Venturi device.

FIG. **5** is a side, perspective view of just the body of the Venturi device of FIG. **4**.

FIG. **6** is a side, perspective, exploded view of an improved embodiment of a Venturi device.

FIG. **7** is a side, plan view of a first embodiment of a check valve insert.

FIG. **8** is a side, perspective view of a second embodiment of a check valve insert.

FIG. **9** is a side, perspective view of a third embodiment of a check valve insert.

FIG. **10** is a side, perspective view of a fourth embodiment of a check valve insert.

FIG. **11** is a side, perspective view of a fifth embodiment of a check valve insert.

FIG. **12** is a side, perspective view of a sixth embodiment of a check valve insert.

FIG. **13** is a longitudinal, cross-section view of a standalone check valve having a check valve insert.

DETAILED DESCRIPTION

The following detailed description will illustrate the general principles of the invention, examples of which are additionally illustrated in the accompanying drawings. In the drawings, like reference numbers indicate identical or functionally similar elements.

As used herein, "fluid" means any liquid, suspension, colloid, gas, plasma, or combinations thereof.

FIG. **1** is an external view of a Venturi device, generally identified by reference number **100**, for use in an engine, for example, a vehicle's engine. The engine may be an internal combustion engine that includes a device requiring a vacuum **102** represented in FIG. **2**. Check valves are normally employed in vehicle systems in the air flow lines, for example, between the intake manifold, downstream of the throttle, and the devices requiring vacuum. The engine and all its components and/or subsystems are not shown in the figures, with the exception of a few boxes included to represent specific components of the engine as identified herein, and it is understood that the engine components and/or subsystems may include any commonly found in vehicle engines. For example, a source of motive flow is fluidly connected to a motive section **116** of the Venturi device **100**, which may be atmospheric pressure or boosted pressure. While the embodiments in the figures are referred to as aspirators because the motive section **116** is connected to atmospheric pressure, the embodiments are not limited thereto. In other embodiments, the motive section **116** may be connected to boosted pressure, such as the pressures attributed to boosted air produced by a turbocharger, and as such the "aspirator" is now preferably referred to as an "ejector."

Referring to FIGS. **1** and **2**, the Venturi device **100** is connected to a device requiring vacuum **102**, and the Venturi device **100** creates vacuum for said device **102** by the flow of air through a passageway **104**, extending generally the length of the body **106**, designed to create the Venturi effect. Passageway **104** has four or more ports that are connectable to an engine or components connected thereto. The ports include: (1) a motive port **108**, which may be connected to a source of clean air, e.g., from the engine intake air cleaner, that is positioned upstream of a throttle; (2 and 3) a pair of suction ports **110***a*, **110***b*; (4) a discharge outlet **112**, which may be connected to an engine intake manifold downstream of the throttle of the engine; and, optionally, (5) one or more bypass ports **114***a*, **114***b*. The motive fluid flow through the passageway **104** travels from the motive port **108** (high pressure) toward the discharge outlet **112** (low pressure). In the illustrated embodiment, the suction ports **110***a*, **110***b* are each in fluid communication with a port **154** and an optional auxiliary port **115** via suction housings **107***a* and **107***b*, respectively. The ports **154** may function as inlets connecting the Venturi device to a device requiring vacuum **102**. In one embodiment, the device requiring vacuum may be one device connected to both ports **154**, or two separate devices each connected to one port **154** as shown in FIG. **2**. An additional device requiring vacuum may be connected to one or more of the auxiliary ports **115**. Each of the respective ports **108**, **112**, **115**, and **154** may include a connector feature **117** on the outer surface thereof for connecting the respective port to a hose or other component in the engine.

In FIGS. **1** and **2**, the body **106** is connected to the upper suction housing **107***a* and to the lower suction housing **107***b* with sealingly tight connections. In the illustrated embodiment, upper housing portion **107***a* and lower housing portion **107***b* are identical aside from their attachment locations relative to the body **106**, but suction housings **107***a*, **107***b* need not be identical nor are they required to include all of the same components (for example, in an embodiment with only one bypass port **114**, the pertinent features of one of the suction housings **107***a*, **107***b*, and the corresponding connective features of body **106**, are omitted). The designations of upper, lower, and middle portions are relative to the drawings as oriented on the page, for descriptive purposes, and are not limited to the illustrated orientation when utilized in an engine system. The upper and lower suction housings are joined to the body **106**, for example by sonic welding, heating, or other conventional methods for forming an airtight or fluidtight seal therebetween.

Still referring to FIGS. **1** and **2**, in the illustrated embodiment, check valves **120***a* and **120***b* and **121***a* and **121***b* are integrated into the Venturi device **100** between the suction housings **107***a* and **107***b* and their respective suction ports **110***a* and **110***b* and bypass ports **114***a* and **114***b*. Alternately, any one or more of the check valves **120***a*, **120***b*, **121***a*, **121***b* may be omitted or may be provided as an external component of an aspirator system. Check valves **120***a*, **120***b* are preferably arranged to prevent fluid from flowing from the suction ports **110***a*, **110***b* to the application device **102**. In one embodiment, the device requiring vacuum **102** is a vehicle brake boost device, a fuel vapor purging system, an automatic transmission, or pneumatic or hydraulic valve, but is not limited thereto.

The check valves **120***a*, **120***b* each include a first valve seat **124**, **126** as part of the body **106**. The first valve seat **124** defines the first suction port **110***a*, and the second valve seat **126** defines the second suction port **110***b*, which both allow for air flow communication with air passageway **104**. In FIG. **2**, the first valve seat **124** includes a plurality of radially spaced fingers **142** and the second valve seat **126** includes a plurality of radially spaced fingers **144** extending into a cavity **123***a*, **123***b* defined by the check valves **120***a*, **120***b* to form a support/seat for a seal disc **111***a*, **111***b*. The check valves **120***a*, **120***b* also include a second valve seat **125**, **127** as part of the suction housings **107***a* and **107***b* against which the seal disc **111***a*, **111***b* can be seated, for example, in a closed position of the check valve. Similarly, check valves **121***a*, **121***b* for the bypass ports **114***a*, **114***b* include generally the same components as check valves **120**a and **120**b and as such, the labels are not repeated in the drawings other than for seal discs **111**c, **111**d.

The body **106** defines passageway **104** along a central longitudinal axis B bisected by the suction ports **110**a, **110**b. The inner passageway **104** includes a first tapering portion **128** (also referred to herein as the motive cone) in the motive section **116** of the body **106** coupled to a second tapering portion **129** (also referred to herein as the discharge cone) in the discharge section **146** of the body **106**. Here, the first tapering portion **128** and the second tapering portion **129** are aligned end to end having the motive outlet end **132** facing the discharge inlet end **134** and defining a Venturi gap **152** therebetween, which defines a fluid junction placing the suction ports **110**a, **110**b generally opposite one another and each in fluid communication with the Venturi gap, and, hence, both the motive section **116** and the discharge section **146**. The Venturi gap **152** as used herein means the lineal distance of the void between the motive outlet end **132** and the discharge inlet end **134**. The interior surface of the motive outlet end **132** and the discharge inlet end **134** are both ellipse-shaped but may alternately have a polygonal form or other curved form.

The bypass ports **114**a, **114**b may intersect the second tapering section **129** adjacent to, but downstream of, the discharge outlet end **136**. The body **106** may thereafter, i.e., downstream of this intersection of the bypass port **114**, continue with a cylindrically uniform inner diameter until it terminates at the aspirator outlet **112**. In another embodiment (not shown), the bypass ports **114**a, **114**b and/or the suction ports **110**a, **110**b may be canted relative to axis B and/or to one another. In the embodiment of FIGS. **1** and **2**, the suction ports **110**a, **110**b and the bypass ports **114**a, **114**b are aligned with one another and have the same orientation relative to the body's central longitudinal axis B. In another embodiment, not shown, the suction ports **110**a, **110**b and the bypass ports **114**a, **114**b may be offset from one another and can be positioned relative to components within the engine that they will connect to for ease of connection. The disclosed system, incorporating a pair of suction ports **110**a, **110**b on either side of the Venturi gap **152**, also provides improved suction flow rate for a given motive flow and discharge pressure as compared to a system incorporating a single suction port **110** because the disclosed system provides greater capacity to utilize the Venturi effect created by the motive flow through passageway **104**.

Referring now to FIG. **3**, an alternate embodiment of the body of a Venturi device, generally designated **206**, is disclosed. The body **206** defines a passageway generally equivalent to passage **104** described above and has a variety of ports including a motive port **208**, a pair of suction ports **210**a, **210**b, a discharge outlet **212**, and dual bypass ports **214**a, **214**b. As shown in FIGS. **1** and **2**, the body **206** is mateable to suction housings **107**a, **107**b to together form at least one check valve, and may have any combination thereof, including all four check valves as shown in FIG. **2**. The body **306** further defines a chamber **256** spacing the first suction port **210**a and the second suction port **210**b apart from one another by a distance D_{200}. The motive outlet end **232** extends into the chamber **256** at a position where the chamber **256** provides fluid flow around the entire outer surface of the motive outlet end **232**, and the discharge inlet end **234** extends into the chamber **256** at a position where the chamber **256** provides fluid flow around the entire outer surface of the inlet end **234**. The width of the Venturi gap **252** tapers symmetrically generally proximate the first suction port **210**a and the second suction port **210**b (the widest points) toward a central point therebetween, as described in co-owned U.S. application Ser. No. 14/734,228, filed Jun. 9, 2015. Accordingly, the Venturi gap **252** is wider proximate both the first suction port **210**a and the second suction port **210**b than at a generally central point between the first and second suction ports **210**a, **210**b.

The chamber **256** defined by the body **306** includes a plurality of fingers **242** extending radially inward and axially away (upward in the figures) from the passageway of the body **206**. The plurality of fingers **242** are arranged radially as protrusion from an inner wall of the chamber **256** in an orientation where immediately adjacent neighboring fingers are spaced a distance apart from one another. The plurality of fingers **242** define a seat for a seal disc as part of check valve, such as check valve **120**a. Similarly, the check valve **121**a, if the bypass port(s) **214**a is present, has a chamber **266** defined by the body **206** that includes a plurality of fingers **242'** extending radially inward and radially away (upward in the drawings) from the passageway of the body **206** that collectively define a seat for a seal disc. The plurality of fingers **242'** are arranged radially as protrusion from an inner wall of the chamber **266** in an orientation where immediately adjacent neighboring fingers are spaced a distance apart from one another. Each of the plurality of fingers **242**, **242'** has a base that is wider than at an apex thereof.

The apexes of the plurality of fingers **242** collectively define the seat for the seal disc for an open position, and the apexes of fingers **242'** define the seat for a second seal disc for an open position. In the embodiment of FIG. **2**, since check valves **120**b and **121**b are present, each of the plurality of fingers **242** in the embodiment of FIG. **3** include a mirror image finger **244** beginning at its base and projecting axially away from the base and terminating at an apex. The mirror image fingers **244** are integral with the fingers **242**. The apexes of the mirror image fingers **244** collectively define the seat for another seal disc **111**b. Similarly, the mirror image fingers **244'**, if the fingers **242'** are present, are integral with the plurality of fingers **242'**, begin at the base thereof, and extend axially away from the base thereof (downward in the figures). The apexes of the plurality of mirror image fingers **244'** define the seat for seal disc **111**d.

Referring now to FIGS. **4** and **5**, an alternate embodiment of a Venturi device, generally designated **400**, is disclosed. The Venturi device **400** is connected to a device requiring vacuum **102** and includes a body **406** defining passageway **404** and having a variety of ports including a motive port **408**, a pair of suction ports **410**a, **410**b, an aspirator outlet **412**, a suction housing **407** connected to the body **406** with fluidtight/airtight seals, for example by sonic welding, heating, or other conventional methods for forming such seals therebetween, and, optionally, dual bypass ports **414**a, **414**b. The suction housing **407** and the body **406**, together, form check valve **420** and/or **421**, which if present include a seal disc **411**, **411'**, respectively. Additionally, Venturi device **400** includes a first cap **409**a and a second cap **409**b defining an end of the chamber **456** and an end of chamber **466**, respectively. The first and second caps **409**a, **409**b are connected thereto with fluidtight/airtight seals, for example by sonic welding, heating, or other conventional methods for forming such seals. Components of the Venturi device **400** not described below are understood to be analogous to those described above with respect to the other embodiments.

The body **406** defines passageway **404** along a central longitudinal axis bisected by the suction ports **410**a, **410**b. The inner passageway **404** includes a first tapering portion **428** and the second tapering portion **429** aligned end to end with the motive outlet end **432** facing the discharge inlet end **434** and defining a Venturi gap **452** therebetween. The body **406** further defines a chamber **456** spacing the first suction port **410***a* and the second suction port **410***b* apart from one another by a distance D_{400} labeled in FIG. **5**. The motive outlet end **432** extends into the chamber **456** at a position where the chamber **456** provides fluid flow around the entire outer surface of the motive outlet end **432**, and the discharge inlet end **434** extends into the chamber **456** at a position where the chamber **456** provides fluid flow around the entire outer surface of the inlet end **434**.

The chamber **456** defined by the body **406** includes a plurality of fingers **442** extending radially inward and axially away (upward in the figures) from the passageway **404** of the body **406**. The plurality of fingers **442** are arranged radially as protrusion from an inner wall of the chamber **456** in an orientation where immediately adjacent neighboring fingers are spaced a distance apart from one another. The plurality of fingers **442** define a seat for the seal disc **411** as part of check valve **420**. Similarly, the check valve **421**, if the bypass port(s) **414***a*, **414***b* are present, has a chamber **466** defined by the body **406** that includes a plurality of fingers **442'** extending radially inward and radially away (upward in the drawings) from the passageway **404** of the body **406** that collectively define a seat for the seal disc **411'**. The plurality of fingers **442'** are arranged radially as protrusion from an inner wall of the chamber **466** in an orientation where immediately adjacent neighboring fingers are spaced a distance apart from one another. Each of the plurality of fingers **442**, **442'** has a base that is wider than at an apex thereof. The apexes of the plurality of fingers **442** collectively define the seat for the seal disc **411** for an open position, and the apexes of fingers **442'** define the seat for seal disc **411'** for an open position.

The Venturi devices described above are very durable and effective for producing vacuum for an engine. Improvements, however, are always desirable, especially if the improvement can lengthen the lifetime wear of a component of the device. After much testing and trials, it has been found that the discontinuous or interrupted surface that the plurality of fingers **142**, **242**, **244**, and **442** define as the first valve seat for the seal disc **111**, **411** contributes stress to the seal disc **111**, **411** over the life of the Venturi device. As such, an improvement has been developed, as shown in FIGS. **6-13**, that reduces the stress on the seal disk **511** by providing a continuous surface as the first valve seat **524** against which the seal disc **511** seats in an open position of the check valve. This improvement not only reduces the stress on the seal disc over the life of the Venturi device, it provides a reduction in air flow resistance or restriction as the air flows through the check valve.

Furthermore, by making the first valve seat **524** part of a check valve insert **505** additional advantages have been realized. The check valve insert **505** can be made of a different material than the body **506** and/or the suction housing **507**. The material selected for the check valve insert **505** is less abrasive and/or less rigid than the material selected for the body **506** and/or the suction housing **507**. For example, the body **506** and/or the suction housing **507** may be made of a high glass fiber-filled plastic or a mineral filled plastic. In contrast, the check valve insert **505** may now be made of pure plastics (non-filled plastics) or rubbers, such as EPDM. Another advantage is the ability to select a check valve insert **505** from a plurality of configurations (see FIGS. **6-12**) to tailor the performance characteristics of the Venturi device to the system in which it will operate.

Turning to FIGS. **7-12**, variations of the check valve insert **505** are shown. Each of the check valve inserts **505***a*-**505***f* define a first seat **524** for an open position of a check valve unit, such as any of the check valve units in the Venturi devices disclosed herein or in a stand-alone check valve, such as the one in FIG. **13**. Each check valve insert **505***a*-**505***f* has an outer support **570** seatable in an internal chamber **556**, **566**, **606** of a check valve unit **500**, **600** (FIGS. **6** and **13**). The outer support **570** has an upper surface **571** and a lower surface **572**. Each check valve insert **505***a*-**505***f* has an inner annular ring **574** spaced radially inward from the outer support **570** by a rib **576** that angles axially toward a central longitudinal axis C to position an upper surface **575** of the inner annular ring **574** a distance axially D_1 (labeled in FIG. **7**) beyond the upper surface **571** of the outer support. As shown in FIGS. **7** and **8**, the check valve insert **50** may have ten ribs connecting the inner annular ring **574** to the outer support **570**. As shown in FIGS. **9-11**, the check valve insert **505** may have four ribs **576** connecting the inner annular ring **574** to the outer support **570**. As shown in FIG. **12**, the check valve insert **505** may have two ribs **576** connecting the inner annular ring **574** to the outer support **570**. These are just example embodiments and any number of ribs are possible, including a single rib.

The outer support **570** is illustrated in FIGS. **6-13** as an annular ring that is circular but is not limited thereto. In other embodiments, the outer support **570** may be oval or may be a polygonal-shaped ring. The inner annular ring **574** is typically circular in shape as shown in FIGS. **6**, **8**, **9**, **11**, and **12** or is oval in shape as shown in FIG. **10**. The inner annular ring **574** in addition to being circular or oval in shape may have various configurations for the upper surface **575**. In the embodiments illustrated in FIGS. **6**, **8**, and **11**, the upper surface **575** is a continuous surface in one plane perpendicular to the central longitudinal axis C. In the embodiments illustrated in FIGS. **9**, **10**, and **12**, the upper surface **575** undulates with two opposing troughs **579**. In the embodiment, illustrated in FIG. **7**, the upper surface **575** is angled downward and radially outward toward the outer support **570** over a minor arc extending 20 degrees up to 170 degrees along the inner annular ring **574**, thereby defining an inclined surface portion **580** of the upper surface.

Turning now to FIG. **6**, a Venturi device, generally designated **500**, is disclosed that includes the check valve insert **505** described above. The Venturi device **500** may be connected to a device requiring vacuum, in particular one in an engine system, and includes a body **506** defining an extending from a motive port **508** to a discharge port **512**. Additional ports of the body **506** include a pair of suction ports **510***a*, **510***b* and, optionally, dual bypass ports **514***a*, **514***b*. The suction port **510***a* and bypass port **514***a* (if present) are connected to a suction housing **407** with fluidtight/airtight seals, for example by sonic welding, heating, or other conventional methods for forming such seals. The suction housing **507** and the body **506**, together, form check valve **520** and/or **521**, which if present, each include a seal disc **511**. The suction port **510***b* and bypass port **514***b* may be connected to a second suction housing as shown in FIG. **2**, and if so, may each include a check valve insert **505** and a seal disc **511** in the same manner as check valves **520** and **521**, or may be sealingly closed by integral bottoms or caps as shown in FIG. **4** (without a check valve or check valve insert present). Components of the Venturi device **500** not described below are understood to be analogous to those described above with respect to the other embodiments.

The body **506** has a first tapering portion and the second tapering portion aligned end to end with the motive outlet end **532** facing the discharge inlet end **534** and defining a Venturi gap **552** therebetween. The body **506** further defines a chamber **556** spacing the first suction port **510***a* and the second suction port **510***b* apart from one another by a distance D_2 at positions that are generally opposite one another, but both in fluid communication with the Venturi gap. The motive outlet end **532** extends into the chamber **556** at a position where the chamber **556** provides fluid flow around the entire outer surface of the motive outlet end **532**, and the discharge inlet end **534** extends into the chamber **556** at a position where the chamber **556** provides fluid flow around the entire outer surface of the inlet end **534**.

The chamber **556** and chamber **566** each have a first shoulder **530** protruding inward to define a seat to receive and retain one of the check valve inserts **505***a*-**505***f* A lower surface **572** of the check valve insert **505** is seated against the shoulder **530** to retain the check valve insert **505** in a position a pre-selected distance between the Venturi gap **552** and the first suction port **510***a* or bypass port **514***a*, respectively, to place the open position for the seal disc **511** at a preselected location. A seal disc **511** moveable within a chamber between an open position seated on the first valve seat **524** defined by the inner annular ring **575** of the first check valve insert **505** and a closed position is also housed with each of chambers **556** and **566**, if both are present. Each seal disc **511** is translatable in response to a pressure difference across the opposing major surfaces of each seal disc itself.

Turning now to FIG. **13**, a stand-alone check valve **600** is shown in an exploded view. The check valve **600** includes a housing **602***a*, **602***b* defining an internal cavity **606** in the assembled position (assembled with a fluidtight/airtight seal) having a pin **664** therein upon which is seated a seal disc **611** and defining a first port **608** in fluid communication with the internal cavity **606** and a second port **612** in fluid communication with the internal cavity **606**, thereby defining a flow path from the first port through the chamber to the second port, or vice versa. The internal cavity **606** typically has larger dimensions than the first port **608** and the second port **612**. In the illustrated embodiments, the first port **608** and the second port **612** are positioned opposite one another to define a generally linear flow path through the check valve **600**, when the seal disc **611** is not present, but is not limited to this configuration. The portion of the housing defining the internal cavity **606** includes an internal first seat **524** upon which the seal disc seats when the check valve is open and a second seat **626** upon which the seal disc seats when the check valve is open. Here, the first seat **524** is defined by any of the check valve inserts **505** described herein, and the second seat **626** is one or more features on an inner surface of the internal cavity **606**.

The internal cavity **606** has a shoulder **630** protruding inward that defines a seat for any other retaining feature to receive the check valve insert **505**. A lower surface **572** of the check valve insert **505** is seated against the shoulder **630** to retain the check valve insert **505** in a preselected position within the internal cavity **606** to place the open position for the seal disc **611** at a preselected location. The seal disc **611** is moveable within the internal cavity **606** between the open position seated on the first valve seat **524** defined by an inner annular ring **574** of the check valve insert **505** and a closed position seated on the second valve seat **626**. The seal disc **611** is translatable in response to a pressure differential across the opposing surfaces thereof.

In all embodiments, the check valve insert **505** may be pressfit within the housing or may have a snapfit thereto.

The seal disc **511**, **611** may be made of a rigid material and as such can be seated against the first valve seat **524** of a check valve insert in an angled position relative to the central longitudinal axis C. In another embodiment, the seal disc **511**, **611** may be flexible such that it can conform by bending to the shape defined by the upper surface **575** of the inner annular ring **574** of a check valve insert **505**. The seal disc **511**, **611** may be made of or may include an elastomeric material suitable for use under conditions existing in an operating system, such as an engine, i.e., engine temperatures and pressures. In one embodiment, the seal disc comprises a natural rubber, synthetic rubber, silicones, fluorosilicones, fluorocarbons, nitriles, EPDM, PTFE, or combinations thereof, but is not limited thereto.

The check valve insert as a separate and discrete component of the check valve is easier to manufacture, provides a more robust construction, and is an easier means to vary the construction of the check valve, i.e., changing the number of ribs or shape/contour of the inner annular ring. It improves the moldability of the check valve insert by reducing sink marks resulting from the injection molding process of plastics. Sink marks develop when material in the region of features such as ribs or bosses shrink more than material in the adjacent wall because of differential rates of cooling as a result of different thicknesses. Also, it improves the moldability of the lower body by removing features from the lower body that may have made it more difficult to lock core pins together. For example, it is easier to access the Venturi gap to lock core pins together, which assures that the motive and discharge ports are aligned, thereby providing for overall better performance of the Venturi device. Additionally, the check valve insert provides better support for the sealing disc with less section flow restriction because of the presence of the inner annular ring. The inner annular ring also enables the ribs to be thinner and fewer in number than individual fingers that defined the valve seat in the prior art.

Having described the invention in detail and by reference to preferred embodiments thereof, it will be apparent that modifications and variations are possible without departing from the scope of the invention which is defined in the appended claims.

What is claimed is:

1. A check valve insert defining a first seat for an open position of a check valve unit, the check valve insert comprising:

- an outer support ring seatable in an internal chamber of a check valve unit and having an upper surface, and a lower surface; and
- an inner annular ring spaced radially inward from the outer support by a plurality of ribs that each angle axially toward a central longitudinal axis to position an upper surface of the inner annular ring a distance axially beyond the upper surface of the outer support;
  - wherein the inner annular ring defines a first flow path through the check valve insert in alignment with the central longitudinal axis, and immediately neighboring ribs of the plurality of ribs are spaced apart from one another and define secondary flow paths axially through the check valve insert that are parallel to the first flow path;
- wherein the upper surface of the inner annular ring undulates with two opposing troughs or the upper surface, along a minor arc extending 20 degrees up to 170 degrees of the 360 degrees of the inner annular ring, is angled downward axially and radially outward toward the outer support, thereby defining an inclined surface portion of the upper surface.

2. The check valve insert of claim 1, wherein the outer support is an annular ring or a polygonal-shaped ring.

3. The check valve insert of claim 1, wherein the inner annular ring is circular or oval in shape.

4. A check valve unit comprising:

a two-part housing comprising a first housing part defining an inlet port and a second housing part defining an outlet port, wherein, when sealingly mated together, the first housing part and the second housing part collectively define a chamber in fluid communication with the inlet port and the outlet port, thereby defining a flow path from the inlet port through the chamber to the outlet port, wherein the chamber defines a seal seat for a closed position and either of the first housing part or the second housing part has a shoulder protruding inward into the chamber;

a check valve insert seated on the shoulder in the chamber, the check valve insert comprising:

an outer support having an upper surface and a lower surface, wherein the lower surface of the outer support is seated on the shoulder in the chamber; and

an inner annular ring spaced radially inward from the outer support by a rib that angles axially toward a central longitudinal axis to position an upper surface of the inner annular ring a distance axially beyond the upper surface of the outer support;

wherein the upper surface of the inner annular ring undulates with two opposing troughs or the upper surface, along a minor arc extending 20 degrees up to 170 degrees of the 360 degrees of the inner annular ring, is angled downward axially and radially outward toward the outer support, thereby defining an inclined surface portion of the upper surface; and

a seal disc translatable linearly within the chamber in response to a pressure difference across the seal disc itself to move the seal disc from an open position seated on the upper surface of the inner annular ring of the check valve insert to the closed position seated solely against the seal seat of the chamber.

5. The check valve unit of claim 4, wherein the outer support is an annular ring or a polygonal-shaped ring.

6. The check valve unit of claim 4, wherein the inner annular ring is circular or oval in shape.

7. The check valve unit of claim 4, wherein a plurality of circumferentially spaced apart ribs space the inner annular ring from the outer support.

8. The check valve unit of claim 4, wherein the outlet port is a Venturi gap of a Venturi device.

9. The check valve unit of claim 4, wherein the outlet port is a bypass port of a Venturi device.

10. The check valve unit of claim 9, wherein the bypass port is positioned downstream of a Venturi gap.

11. A Venturi device comprising:

a body defining a passageway having a motive section and a discharge section spaced a distance apart from one another to define a Venturi gap, both of which converge toward the Venturi gap, and defining a chamber housing the Venturi gap and having a first suction port in fluid communication with the Venturi gap; wherein the chamber has a first shoulder protruding inward and positioned a pre-selected distance between the Venturi gap and the first suction port;

a first check valve insert seated on the first shoulder in the chamber, the check valve insert comprising:

an outer support ring seatable in the chamber and having an upper surface and a lower surface; and

an inner annular ring spaced radially inward from the outer support by a plurality of ribs that each angle axially toward a central longitudinal axis to position an upper surface of the inner annular ring a distance axially beyond the upper surface of the outer support,

wherein the upper surface of the inner annular ring undulates with two opposing troughs or the upper surface, along a minor arc extending 20 degrees up to 170 degrees of the 360 degrees of the inner annular ring, is angled downward axially and radially outward toward the outer support, thereby defining an inclined surface portion of the upper surface;

wherein the inner annular ring defines a first flow path through the check valve insert in alignment with the central longitudinal axis, and immediately neighboring ribs of the plurality of ribs are spaced apart from one another and define secondary flow paths axially through the check valve insert that are parallel to the first plow flow path; and

a first seal disc moveable within the chamber between an open position seated on the upper surface of the inner annular ring of the first check valve insert and a closed position; wherein the first seal disc is translatable in response to a pressure difference across the first seal disc itself; and

a first suction housing sealingly connected to the first suction port to collectively form a first check valve chamber; wherein the suction housing defines a valve seat for the closed position.

12. The Venturi device of claim 11, wherein the body further defines a second suction port in fluid communication with the Venturi gap.

13. The Venturi device of claim 12, further comprising a cap sealingly connected to the second suction port of the body.

14. The Venturi device of claim 12, further comprising a second suction housing sealingly connected to the second suction port of the body to collectively form a second check valve chamber.

15. The Venturi device of claim 11, wherein the chamber has a second shoulder protruding inward and positioned a pre-selected distance between the Venturi gap and the second suction port, and a second check valve insert seated on the second shoulder in the chamber, the second check valve insert comprising:

an outer support seatable in the chamber and having an upper surface and a lower surface; and

an inner annular ring spaced radially inward from the outer support by a rib that angles axially toward a central longitudinal axis to position an upper surface of the inner annular ring a distance axially beyond the upper surface of the outer support.

16. The Venturi device of claim 15, further comprising a second seal disc moveable within the second check valve chamber between an open position seated on the upper surface of the inner annular ring of the second check valve insert and a closed position; wherein the second seal disc is translatable in response to a pressure difference across the second seal disc itself.

17. The Venturi device of claim 11, wherein an outlet end of the motive section extends into the chamber defined by the body at a position where the chamber provides fluid flow around the entire outer surface of the outlet end, and an inlet end of the discharge section extends into the chamber at a

position where the chamber provides fluid flow around the entire outer surface of the inlet end of the discharge section.

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